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Montezuma quail (*Cyrtonyx montezumae*) represent one of the least studied North American quail species, particularly in Texas. This lack of information may be partly due to their secretive nature and difficulty of capturing. We provide the first published report of fate of radio-marked Montezuma quail in Texas. We captured, radio-marked, and released 14 Montezuma quail on Elephant Mountain ($n = 9$) and Davis Mountain Preserve ($n = 5$) during 2000-2005. We used 2 methods of attachment for pendant style neck-loop radio transmitters. Body-loop transmitters were affixed to quail captured at the Davis Mountain Preserve whereas both body-loop and neck-loop were used at Elephant Mountain. All radio-marked Montezuma quail died within a relatively short period (1-16 days). Causes of mortality for most Montezuma quail were attributed to raptors ($n = 9$), mammals ($n = 1$), and miscellaneous ($n = 4$). Because this low survival rate would not sustain a natural population, we suspect trapping, handling, and/or radio-marking negatively affected survival. It is possible that transmitters potentially restricted escape movements or interfered with other behavior thereby making Montezuma quail more vulnerable to predation. Traditional techniques used to affix radio transmitters or transmitter design itself need to be refined if Montezuma quail are to be studied using radio telemetry.

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Key words: *Cyrtonyx montezumae*, Montezuma quail, radio-marked, radio telemetry, survival

Introduction

Montezuma quail (*Cyrtonyx montezumae*) are secretive birds that are associated with pine-oak woodlands of the desert southwest (Stromberg 2000). In New Mexico (Holdermann 1992) and Arizona (Heffelfinger and Olding 2000), Montezuma quail are classified as game birds and provide a valuable source of recreational opportunities for hunters. In Texas, Montezuma quail are also classified as game birds but have a closed season. Throughout the United States, Montezuma quail are appreciated and sought by bird watchers and other outdoor enthusiasts. Contrary to their monetary or intrinsic value, little information exists on the ecology of Montezuma quail. Most ecological information on Montezuma quail has been inferred from reports from early naturalists (Fuertes 1903, Ligon 1927, Leopold and McCabe 1957) or from harvested samples (Bishop and Hungerford 1965, Brown and Gutiérrez 1980). Only one study (Stromberg 1990) has provided data on the population ecology of Montezuma quail using contemporary techniques (e.g., radiotelemetry).

The advent of radiotelemetry has had a profound effect on the ability of wildlife biologists to obtain valuable information on the ecology of various wildlife species (Samuel and Fuller 1996). In fact, radiotelemetry has allowed researchers to refine the life history of several quail species. For example, the reproductive strategy for northern bobwhite quail (*Colinus virginianus*) was labeled as "monogamous" by many early researchers (Stoddard 1931, Klimstra and Roseberry 1975). It was not until extensive research using radiotelemetry that biologists discovered that northern bobwhite had a very complicated reproductive strategy that implements a combination of monogamy, polyandry, double clutches, and multiple brooding (Curtis et al. 1993, Burger et al. 1995).

One of the major assumptions of using ra-

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diotelemetry is that the transmitter does not affect the animal's movement or survival. Collectively, manufacturers and biologists have developed light weight transmitters that are affixed with minimal effect on the behavior and survival of the animals. For quail, transmitters are designed to be <5% of the quail's body mass and are typically affixed as neck-loops or backpacks (B. Mueller, American Wildlife Enterprises, Inc., Tallahassee Florida, personal communication). Stromberg (1990) provides the only published account of using radiotelemetry on Montezuma quail. Stromberg (1990) postulated that because of the unique foraging style of Montezuma quail (e.g., digging), the poncho-style transmitter interfered with their behavior and thus survival.

In 2000 we initiated a study investigating the ecology of Montezuma quail in the Trans-Pecos ecoregion of Texas. Because little information exists on the use of radiotelemetry on Montezuma quail, we provide a detailed account on the handling, radiotagging, transplanting, and subsequent fate of radio-marked Montezuma quail.

Study Area

This study was conducted on Elephant Mountain Wildlife Management Area (WMA) and the Davis Mountain Preserve. The two study sites are approximately 108 km apart and located in the Trans-Pecos ecoregion of Texas. Precipitation for both sites varied form 38-51 cm at Elephant Mountain to 45-58 cm at the Davis Mountain Preserve. Most of the precipitation fell as torrential rains during the months of July-August. Other precipitation occurred in the form of snow during December and January.

Elephant Mountain WMA is located 40 km south of Alpine, Texas in Brewster County. The actual study location was the summit and slopes of Elephant Mountain which is situated in the center of the WMA. Elephant Mountain ranges in elevation from 1,615 m in the north side to 1,900 m in the southern end and rises approximately 609 m above the surrounding table lands. Vegetation found at Elephant Mountain WMA was typical of the Chihuahuan Desert. The lowlands surrounding Elephant Mountain were composed of desert scrub species and the top of Elephant Mountain was desert grassland interspersed with small shrubs. The small shrubs include oak (*Quercus* spp.), mountain laurel (*Sophora secundiflora*), and fragrant sumac (*Rhus aromatica*).

The Davis Mountain Preserve encompasses 7,300 ha of West Texas montane habitat in Jeff Davis County approximately 25 km northwest of Fort Davis, Texas. Elevation ranges from 1,700 m to over 2,000 m. The lower elevations were composed of mainly oak savannah vegetation. The dominant grasses included cane bluestem (*Bothriochloa barbinodis*), side-oats grama (*Bouteloua curtipendula*), and blue grama (*Bouteloua gracilis*). Typical woody species included ponderosa pine (*Pinus ponderosa*), white pine (*Pinus strobiformis*), Mexican pinyon (*Pinus cembroides*), and alligator juniper (*Juniperus deppeana*).

Methods

A total of 14 Montezuma quail were captured, radio-marked and released on Elephant Mountain ($n = 9$) and Davis Mountain Preserve ($n = 5$) during 2000 and 2005, respectively. The methods employed to capture quail included mist nets, trained bird dogs and fishing dip nets, and night-netting.

The mist net capture method consisted of visually detecting quail, carefully approaching and slowly lowering the mist net over the quail. The observers would then quickly remove the captured quail from the mist net and proceed to data collection (e.g. sex, age, weight, etc.)

Trained bird dogs were used to aide in detecting quail. Once the dog located the quail (on point), 2-3 observers with fishing dip nets would approach the point location. To capture the quail, the observers would either visually detect the quail and lower the dip net, or capture on the wing as they flushed up.

Night netting involved having at least one radio-marked quail in the covey. The radio-marked quail were located (via radio telemetry) at night while on roost and a general location (2m x 2m area) was determined by triangulation. The exact location was revealed by shining a spotlight on the general location until the roosting covey was detected. A fishing net was then slowly lowered on the covey.

All quail captured were aged, sexed, banded, measured, and fitted with a radiotransmitter at time of capture. Quail that weighed >150 g were fitted with either a neck-loop or body-loop style transmitter (American Wildlife Enterprises, Tallahassee, Florida). Handling time was maintained to <5 minutes to minimize stress. Quail that were captured and to be transplanted were kept in a cardboard holding box (46 x 46 x 76 cm) containing grain sorghum and water and transported to a lab. The quail remained undisturbed in captivity overnight and were subsequently transported to release sites. Transplants were conducted to supplement trapping efforts at both study sites. We had experienced minimal to no trapping success at Elephant Mountain as well as at the Davis Mountain Preserve.

At the Elephant Mountain release sites, the quail were released as pairs. Montezuma quail within each pair were separated approximately 100 m to encourage calling between both birds (i.e. assembly call) in hope of attracting surrounding quail. The reasoning was that they would assemble with resident quail. Montezuma quail released at the Davis Mountain Preserve were released as single birds and relocated 300-750 m from original capture site. For transplanted quail, total time elapsed from time of first capture to time of release was <24 hours. For discussion purposes, captured Montezuma quail are referred to by band number (e.g., MQ140) throughout this manuscript.

Results

Elephant Mountain WMA

An adult male Montezuma quail (MQ138) was captured at Elephant Mountain on 20 December 2000 with the aide of a bird dog and a fishing dip net. It was banded and fitted with a neck-loop transmitter. Attempts to radiolocate MQ138 the following day and subsequent ground and aerial searches failed. Approximately 6 months later, the transmitter was located in a large tree along a bluff. Based on the location of the transmitter and the "pig-tailed" appearance of the antenna, it was concluded that MQ138 was preyed upon by a raptor.

Five Montezuma quail (MQ140, MQ141, MQ142, MQ143, and MQ144) ventured onto Sul Ross State University campus on 22 January 2001 and were captured using portable mist nets. Also, taking advantage of the quail's primary defense strategy of laying motionless and hunkering down, some birds were captured by hand. The quail were placed in a cardboard holding box where they remained undisturbed and in captivity overnight.

The following day an adult female (MQ141) was fitted with a body-loop transmitter and transported to the original capture site and released where 3 covey mates avoided capture the day prior. A day later, the carcass of MQ141 was found intact <100 m from release site. Her mortality is attributed to handling stress or exposure.

The remaining 4 quail were translocated to Elephant Mountain, radio-tagged, and released at 2 sites where fresh quail sign (e.g., diggings) had been located. They were released as pairs (F, F and M, F). The two females (MQ144, MQ140) were radio-tagged with a neck-loop (MQ140) and chest-loop (MQ144) style transmitters and released. They were radiolocated and found dead <150 m from release site and <40 m apart from each other the day following the release. The "pig-tailed" antenna indicated raptor predation.

The male-female pair (MQ143, MQ142) was radio-tagged with body-loop style transmitters, released, and located the following day with 3 resident Montezuma quail. MQ143 and MQ142 were recaptured along with the 3 resident quail using the night-netting technique. Because we had been successful at integrating MQ143 and MQ142 with resident quail, we attempted the integration process again by relocating the pair to another release site. MQ143 and MQ142 were found dead the day following their second release. The cause of mortality for both quail was attributed to raptors.

The 3 resident Montezuma quail (MQ145, MQ146, and MQ147) were all fitted with neck-loop style transmitters and released at their original capture site. They were found dead the day after their release. Clipped body parts (i.e., leg, wing, meat stripped off of bones) suggested avian kill.

Davis Mountain Preserve

A female (MQ101) was flushed and caught using a handheld fishing dip net on 25 June 2005. MQ101 was morphologically measured, radio-marked, and released on site. MQ101 subsequently paired up with 3 different males on three separate occasions. These 3 males (MQ104, MQ102, and MQ103) were all captured using the night-netting technique. All quail were kept in captivity in a cardboard holding box overnight and released the morning following their capture. Given the time of year (Montezuma quail pairing season) all quail captured with MQ101 were relocated from release site to prevent pairing up and to encourage MQ101 to pair up with a different male Subsequently, this would allow us to night-net other quail and increase our sample size.

MQ101 survived for 15 days and its mortality was attributed to canid predation. MQ104 was captured with MQ101 on 27 June 2005 and released as a single 750 m from capture site the following morning. MQ104 never joined other Montezuma quail and survived for 12 days. This mortality is attributed to avian predation.

MQ102 was captured with MQ101 on 28 June 2005 and released as a single 700 m from capture site the following morning. MQ102 never joined other quail and survived for at least 12 days. The transmitter signal was lost thereafter and assumed that the signal loss was due to transmitter failure.

MQ103 was captured with MQ101 on 2 July 2005 and released as a single 300 m from capture site the following morning. MQ103 was radiolocated for 16 days until the carcass was found with 1 leg missing.

A fifth Montezuma quail (MQ105) was captured using a trained dog and handheld fishing dip net on 28 October 2005. MQ105 was radiolocated for 3 days and then signal was lost. The transmitter was located 18 days later. The cause of mortality for MQ105 is unknown.

Discussion

Of the 14 Montezuma quail captured, 9 mortalities were attributed to avian predation. The mortality of 1 quail (MQ141) may have been caused by handling stress or exposure to the elements. However, handling stress can be discounted as a cause of mortality, primarily because the other quail were subjected to the same handling procedures and did not show any immediate ill affects. We believe exposure may have contributed to the death of MQ141 for several reasons. First, MQ141 was released alone and did not covey-up. Second, temperatures on the evening of her release fell below 0 C and thermoregulation may have been compromised without roosting with other quail.

The remaining 4 quail mortalities were labeled as mammal ($n = 1$), and miscellaneous ($n = 3$). The miscellaneous category included causes other than predation (e.g., lost signal, transmitter failure, unknown death, etc.).

Previous researchers have documented raptor predation in Montezuma quail (Ligon 1927, Leopold and McCabe 1957, Brown 1982, Stromberg 1990, Holdermann and Holdermann 1993). In fact, Stromberg (1990) suggested that raptors had the tendency to localize their hunting efforts on the same covey.

Although the mortalities in this study may have been natural, other factors may have contributed to the high levels observed. Montezuma quail primarily forage for bulbs and tubers making them extremely difficult to bait into standard funnel traps. Consequently, conventional trapping techniques were useless and we resorted to unconventional methods (i.e. fishing dip nets, mist nets and bird dogs). These unconventional capture techniques were possibly more stressful on the quail. Also, transplanting and releasing away from capture site, releasing in low numbers (i.e. singles or pairs) in addition to being in unfamiliar surroundings perhaps increased their vulnerability to predation. Additionally, unfamiliar surroundings and poor habitat conditions at the release sites, such as the Elephant Mountain site, may have increased their chance of being predated. And lastly, transmitter design potentially restricted movement or interfered with other behavior and contributed to this already stressful arrangement.

Affixing radiotransmitters to quail is a common practice in scientific investigations. Guthery and Lusk (2004) proposed that northern bobwhite are handicapped when radiotransmitters are affixed, thus lowering survival. However, Hernandez et al. (2004) found no difference in body mass, feed consumption, and energy expenditure between collared and un-collared quail. Additionally, Stromberg (1990) noted that no difference was found in life expectancy between radioed and non-radioed Montezuma quail. Although poor attachment can impair mobility and survival of quail, we discount the likelihood that poor attachment played a role in reducing survival of quail in this study. Specifically, the research team had extensive experience in affixing radiotransmitters to 3 quail species and a variety of other gallinaceous birds. Stromberg (1990) suggested that radio attachment on Montezuma quail should be chosen wisely due to their unique foraging behavior.

Another possible explanation for the high mortality documented in this study is that the habitat at the Elephant Mountain release site was in poor condition and did not provide the cover essential for survival. The key component limiting the distribution of Montezuma quail throughout their range is herbaceous cover (Brown 1982). Since they rely on cryptic coloration for concealment and rarely flush, Montezuma quail are especially sensitive to drastic changes in herbaceous cover (Brown 1982, Albers and Gehlbach 1990). In October 2000, Elephant Mountain experienced a drastic freeze that reduced herbaceous cover (S. P. Lerich, Texas Parks and Wildlife Department, unpublished data). In fact, sightings of Montezuma quail were less frequent atop Elephant Mountain following the freeze, suggesting population numbers declined. Because Montezuma quail have limited mobility and defense mechanisms, it is plausible that a reduction in herbaceous cover could increase the vulnerability of quail to avian predation and lead to population reduction. However, this theory does not necessarily apply for the Montezuma quail captured at the Davis Mountain Preserve where cover seemed to be in adequate supply.

Conclusions

Unlike other quail species in North America, Montezuma quail are habitat and foraging specialist. Because of these unique traits, Montezuma quail appear to be susceptible to heavy predation by raptors. Mortality rates may be accelerated if herbaceous cover is reduced to a critical level. The mortality rate of Montezuma quail in this study is similar to that reported by previous researchers (e.g., Stromberg 1990).

The combination of difficulty in capture, stressful capture techniques, moving to and releasing in unfamiliar areas in low numbers, and unconventional capture techniques made studying Montezuma quail extremely challenging. Alternative capture techniques need to be developed and further evaluation of traditional techniques used to affix radio transmitters or transmitter design itself need to be refined if Montezuma quail are to be studied using radio telemetry.

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